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A Method for the Rapid Tenderization of Beef Carcasses[a, b]

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In a previous report on the aging of beef steaks at elevated temperatures *(4)*, results showed that steaks from chilled carcasses could be tenderized by holding them at 110° F for 24 hours. The extent of microbial growth was found to be less severe at this temperature than at 90° F and could be controlled by the injection of antibiotics into the round prior to cutting into steaks. Steaks were used in the previous work to reduce the experimental error with respect to variations in tenderness within and between animals and to facilitate the control of the aging temperatures.

In the present work the results of the previous study were applied in the aging of five beef carcasses immediately post-mortem in a manner which would more nearly approach the probable commercial use of the accelerated aging procedure. Preservation during aging was provided by an ante-mortem injection of oxytetracycline. The limited time-high temperature schedule was compared to a more conventional aging procedure of holding for two weeks at 35° F. Because of the limited number of carcasses, four muscles in each carcass were used to determine the effectiveness of the aging procedures. The preliminary results reported in this paper indicate that beef in the carcass can be tenderized in 24 hours at 110° F. A more thorough investigation with a greater number of carcasses is required before completely dependable conclusions can be drawn regarding the accelerated aging procedure.

EXPERIMENTAL

The animals for this study weighed 900 to 1,000 lb and were selected on the basis of having a predicted carcass grade of U. S. Good. One to 3 hr prior to slaughter each animal was given an injection of oxytetracycline (Biostat).[d] Blood and liver samples were taken at the time of the slaughter for antibiotic assay. Muscle samples were also assayed after aging. Following the dressing procedure, the warm carcass was quartered and taken to the laboratory for aging.

Antibiotic administration and microbial control. Animal number one was injected into the abdominal cavity immediately posterior to the 13th rib with 10 g of oxytetracycline in 100 ml of citric acid and water. Because of the crouched position of the animal at time of injection an undetermined amount of the antitbiotic solution lodged in the muscle tissue and limited the distribution of the antibiotic in the remainder of the carcass.

Other research *(3)* had shown that, though the absorption was slower, a satisfactory distribution of antibiotic could be achieved by an ante-mortem injection in the tail; to avoid further difficulties in administering the antibiotic this procedure was used. The quantities of oxytetracycline (OTC) indicated in Table 1 were put into 40–50 ml of solution and injected intramuscularly along the middle one-third of the tail. The transport of the OTC from the site of injection is indicated by the assays for the antitbiotic in the blood and liver. Tissue levels were considerably lower than those of the blood and liver but were probably sufficient to control microbial growth during subsequent aging.

TABLE 1

The ante-mortem injection of oxytetracycline and its retention in the liver, blood, muscle and tissue

Animal	Quantity of OTC	Site of injection	Time to slaughter	Oxytetracycline (ppm)[1]			
				Rib eye		Liver at slaughter	Blood at slaughter
				14 days 35° F	1 day 110° F		
1	10 g	abdominal cavity	2 hr	0.4		3.8	1.4
2	8 g	tail	3 hr	0.6	0.9	7.4	1.8
3	8 g	tail	3 hr	1.6	1.5	9.4	3.3
4	5 g	tail	2 hr	0.5	0.3	3.8	0.6
5	8 g	tail	3 hr	0.6	0.4	5.7	....

[1] Assays performed by Chas. Pfizer and Company, Inc. Each value represented the average of 5 to 10 assays per sample.

Procedures for determining bacterial counts have been presented previously *(4)*. With the exception of the second carcass the counts of anaerobic bacteria in samples taken from the rib section following aging at 110° F were 10,000 per g or less. In samples from rounds aged at 110° F anaerobic counts did not exceed 80,000 per g with the exception of the second carcass. The extensive anaerobic growth in samples from this carcass did not permit a count to be made at the dilution employed. Water extracts of the same muscles from the carcass were without effect when injected interperitoneally into mice, thus indicating no botulinum toxin was found.

The low order of anaerobic bacterial growth in the remaining carcasses suggests that the high plate counts on samples from the second carcass resulted from sampling methods which permitted contamination and that the high counts did not result from bacterial growth during the aging procedure. However, evidence from this assumption was not sufficient to allow the steaks from this carcass to be served to the taste panel and in this instance only the shear test was used to evaluate the effect of aging on tenderness.

Aging procedures. The right or left hind quarter and the seven rib cut of each carcass was aged at 110° F for 24 hr and the paired quarter and rib were aged for 2 weeks at 35° F.

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[d] Supplied by Chas. Pfizer and Company, Inc.

Two to 3 hr elapsed between time of slaughter and placing the cuts or quarters under the desired aging or chilling conditions. During this time the internal temperature of the rib sections was reduced to approximately 90° F. For this reason the aging room was maintained at 120° F until the internal temperature of the rib approached 110° F. The holding temperature was then reduced to 110° F for the remainder of the 24 hr aging period. Following aging, the cuts were moved to a 20° F chill room for a 15 hr period. The quarters and ribs which were to be aged at 35° F were chilled at 20° F for a 15-hr period and then maintained at 35° F for the remainder of the 14-day aging period. Steaks were removed from the short loin of the side aged at 110° F and compared with similarly located steaks from the remaining side removed after 48 hr chilling.

Sampling procedures. The *semimembranosus, semitendinosus* and the *biceps femoris* of the round and the *longissimus dorsi* of the rib of each carcass were used to compare the effectiveness of the two tenderization procedures.

To determine the extent of tenderization by the high temperature schedule, unaged steaks, removed after chilling from the short loin of the side which was to be aged at 35° F, were compared with the steaks from the side which had undergone aging at 110° F.

In all comparisons similar anatomical locations were chosen in the right and left sides. From these known locations 4 steaks, ¾ in thick, were removed serially. The steaks were broiled according to procedures described previously *(2)*. Either 2 or 4 samples representing the 2 aging treatments were served to a taste panel of 8 members at each judging session. Each judge was asked to score the steaks on a 10-point scale for initial tenderness and for residue and to comment regarding the flavor of the samples. Portions of steaks not used by the taste panel were used to determine shear strength on the Warner Bratzler shear machine. Five to 7 cores one-half inch in diameter were removed from the remaining portion of each steak and brought to 45° F prior to shearing. One shear was performed on each core. In a few instances the steaks were not large enough to provide sufficient samples for shearing.

RESULTS AND DISCUSSION

Preservation during aging. The limited number of carcasses included in the study does not permit conclusions regarding the adequacy of the procedures used for restricting bacterial growth during aging at 110° F. It is significant, however, that anaerobic bacterial counts were at a low level in samples from 4 of the 5 carcasses, particularly the last two for which maximum precautions were taken to avoid contamination during sampling. The data suggest that 0.5 to 1.0 ppm of the broad spectrum antibiotic in muscle tissue is sufficient to control bacterial growth during a 24-hr aging period at 110° F.

Post-slaughter changes during aging. The temperature during aging and chilling was recorded for the round and rib eye muscles. A similar pattern was found for all carcasses. The temperature curve for carcass number three is shown in Figure 1. Under more suitable conditions the aging room would be in close proximity to the dressing operation and the reduction in temperature noted for the rib section at 3 hr could be avoided. The internal temperature of the rounds at the beginning of aging was usually between 103° F and 105° F rising to a maximum of approximately 108° F after 9 hours of high temperature processing. Processing the first carcass at 110° F and 80 ± 2% relative humidity resulted in severe drying of the exposed lean tissues. In aging the remaining four carcasses a relative humidity of 85–90%

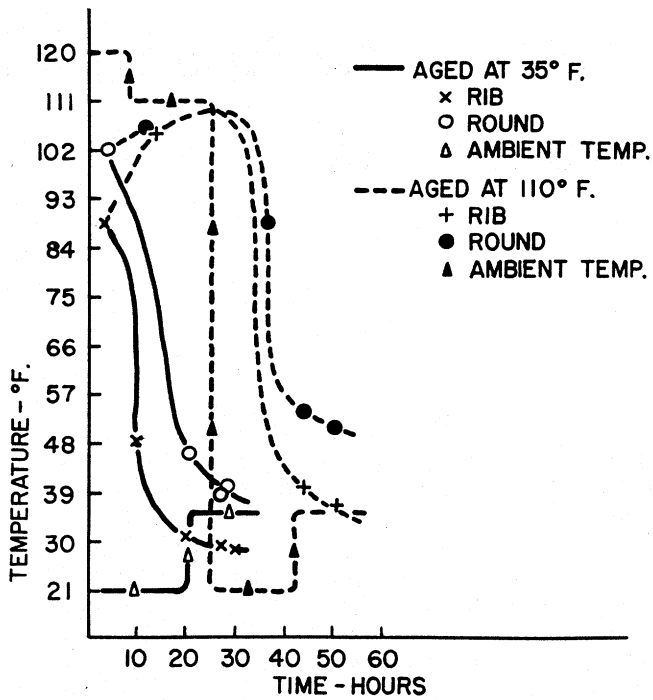

Figure 1. Aging temperature and internal temperature of beef rounds and ribs aged at 35° F and 110° F.

was found to be satisfactory for maintaining carcass appearance and was sufficiently low to restrict mold growth.

During aging, samples were removed periodically for analysis making it difficult to obtain precise data regarding shrinkage. When corrected for sampling, the average weight loss for the rib sections aged at 110° F and 35° F were 3.9 and 4.4%, respectively. The corresponding weight losses for the hindquarters were 2.2 and 2.0%. Deviations about the means were large within both aging temperatures. The losses at 35° F are somewhat less than anticipated from commercial practice but the data indicate that weight losses during aging at 110° F for 24 hr are probably not greater than encountered when carcasses are aged for 2 weeks at 35° F.

Samples of muscle were removed during processing for pH determinations. These values showed a more rapid drop in pH when the meat was held at the elevated temperature. However, at 26–28 hr post slaughter the pH of both sides of the carcasses had reached values (5.4 to 5.7) in the normal range for chilled beef.

Tenderization during aging. Broiled steaks from short loins aged at 110° F for 24 hr were much more tender than broiled steaks from unaged (48 hr post slaughter) short loin (Table 2). The aging procedure caused both a marked increase in initial tenderness and a decrease in the amount of residue (the unmasticated material remaining after chewing). The increase in tenderness was somewhat greater than observed by Deatherage and Rieman *(1)* for unprocessed and "Tenderayed" beef of the Commercial and Good grades. The increase in tenderness due to aging in the present experiment was also greater than had been observed previously when individual steaks were

TABLE 2

Mean tenderness and residue scores[1] for short loin steaks from unaged carcasses and carcasses aged 24 hours at 110° F

Treatment	Initial tenderness		Residue	
	Number of judgments	Score	Number of judgments	Score
Unaged	101	4.7	101	5.5
Aged 24 hr, 110° F	101	7.6***	98	7.7***

*** $P<0.001$.

[1] Score range—1–10 with increasing tenderness; 1–10 with decreasing residue.

aged *(4)*. These differences may be attributed in part to the post-mortem age of the "unaged" controls. In our previous investigation the control steaks were from rounds held 24 to 48 hr longer at cooler temperatures than those used in this study and some tenderization may have accompanied the additional holding period. This may also be applicable to a comparison of the experiments of Deatherage and Rieman with those in the present study.

A comparison between the tenderness measurements of 4 different muscles from carcass sides aged at 35° F and 110° F is shown in Table 3. A statistical analysis

TABLE 3

Mean tenderness, residue scores and shear values of steaks from carcasses aged at 35° F and 110° F

Muscle	Tenderness				Shear test	
	Initial		Residue			
	Number of judgments	Mean	Number of judgments	Mean	Number[1] of shears	Mean
Long. dorsi						
35°–2 wk	118	7.8	118	7.7	77	7.9
110°–24 hr	118	7.5	117	7.5	72	8.5
Semitendinosus						
35°–2 wk	122	7.4	118	7.2	97	9.0
110°–24 hr	122	6.9	120	6.9	81	9.7
Semimembranosus						
35°–2 wk	126	6.2	126	6.1	109	13.0
110°–24 hr	126	6.5	126	6.3	104	10.8
Biceps femoris						
35°–2 wk	109	6.9	109	6.7	118	11.1
110°–24 hr	116	6.5	116	6.4	102	10.8
All Muscles						
35°–2 wk	475	7.1	471	6.9	401	10.5
110°–24 hr	482	6.8	579	6.8	359	10.1

[1] Shear values obtained from 5 carcasses, other values from 4 carcasses.

for each of the 3 measurements of tenderness appears in Table 4. It may be observed in Table 3 that the taste panel scores for both initial tenderness and residue are slightly higher for steaks removed from the *longissimus dorsi, semitendinosus* and *biceps femoris* of sides aged for 2 weeks at 35° F. For the *semimembranosus* muscle the mean tenderness scores are reversed indicating more tenderization occurred in this muscle under accelerated aging conditions. The difference in response of different muscles to the 2 methods of aging is shown further by the significant muscle x method of aging interaction (Table 4). This pattern of tenderness differences was generally true for all of the carcasses studied. These results suggest that the high temperature aging procedure is more

TABLE 4

Analysis of variance for tenderness scores and shear values of carcasses aged at 35° F and 110° F

Source of variation	Tenderness scores				Shear values	
	Initial tenderness		Residue			
	df	ms	df	ms	df	ms
Method of aging	1	12.1*	1	4.3	1	28.6
Muscles	3	76.7**	3	91.3**	3	506.1**
Animals	3	128.3**	3	26.7**	4	270.0**
Muscles × Aging	3	6.6**	3	3.1	3	233.5**
Muscles × Animals	9	21.6**	9	10.9*	12	4.8
Aging × Animals	3	0.3	3	0.9	4	1.6
A × M × A	9	52.9**	9	28.8**	12	108.8**
Error	924	1.6	918	2.1	720	7.8

* Significant at 5% level.
** Significent at 1% level.
df—degrees of freedom.
ms—mean square.

effective on the less tender muscles within the carcass. As indicated in Table 4 the greater mean tenderness score for the 35° F treatment was significantly higher (5% level) than for the 110° F treatment. The differences between residue scores and shear values due to method of aging were not significantly different.

The previous study *(4)* in which *semimembranosus* steaks were aged had shown a slightly greater tenderization effect on the high temperature aging procedure. Considering only the *semimembranosus* steaks used in this study there is excellent agreement between the two procedures employed.

The statistical analyses in Table 4 indicate also the highly significant differences among animals and muscles for each of the scoring procedures. The muscle x animal interaction for taste panel scores shows further that all muscles were not alike in their response to the aging procedures. The *longissimus dorsi* was the most tender and the *semimembranosus* the least tender.

The mean shear value for all muscles (Table 3) was slightly lower (more tender) for steaks from sides aged at 110° F. There is, however, good agreement between the shear values and taste panel scores for tenderness when the 2 methods of aging are compared within and between muscle groupings.

The notations by the taste panel regarding flavor of the broiled steaks indicated a preference for those from sides or ribs aged at 35° F. While comments indicating the presence of old or stale, and slightly bitter flavors were noted for steaks from both treatments, they were applied more frequently to the steaks from sides aged by the accelerated process. The flavors described as unpleasant by some panel members were to other panel members somewhat similar to those noted in beef which has been aged 3 to 4 weeks at 35° F.

SUMMARY

A previous study employing steaks as the experimental unit had indicated that tenderness of beef could be significantly improved by holding the meat at 110° F for 24 hours.

In this study five beef carcasses were employed to determine the desirability of aging meat in the wholesale cut at elevated temperatures to increase tenderness. Two or three hours prior to slaughter 5 to 10 g of oxytetracycline were given intraperitoneally or intramuscularly in 50 to 100 ml of solution. The injection of the antibiotic in several locations in the tail was found convenient and resulted in tissue levels of 0.5 to 1.0 ppm which was usually sufficient to control bacterial growth during aging.

One hindquarter and rib cut of each carcass was aged for 24 hours at 110° F and the corresponding cuts from the remaining side were aged for two weeks at 35° F. The high temperature aging schedule resulted in a significant increase in tenderness in steaks removed from the short loin *(longissimus dorsi)*. Three muscles of the round and the *longissimus dorsi* of the rib were used to compare the two aging procedures. Taste panel results showed a slightly greater tenderization effect of the 35° F aging procedure. Slight flavor changes were noted in some of the steaks from sides aged at 110° F.

The limited number of carcasses in this study does not permit definite conclusions regarding the commercial application of the accelerated aging procedure. The data show, however, that significant tenderization can be achieved in beef by holding the carcasses at 110° F for 24 hours after slaughter.

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